ON THE STRUCTURE OF MARINE AIR OVER THE SAN FERNANDO VALLEY, CALIFORNIA, IN RELATION TO FORECASTING SUMMERTIME STRATUS

By H. E. Hutchison and K. C. Fink

[Weather Bureau, Burbank, Calif., June 1939]

During the past ten years a considerable volume of material has been written on the subject of California's coastal stratus and inland valley fogs. Studies by Bowie, Vernon, Blake, Petterssen, and others [1] have established knowledge of the general cause and behavior of the phenomenon. It has been shown that a relatively warm, dry air mass above a comparatively shallow, cool, unstable layer is always involved; that the base of the temperature and humidity discontinuity between the two strata is almost without exception the point of first formation of the stratus; that it builds downward from that point as cooling through radiation takes place at night; and that it dissipates upward from the base of the cloud rather than downward from the top during the day.

The whole subject has heretofore been studied mainly on the basis of observations made along the immediate coast and over areas connecting immediately with the coast. The San Fernando Valley, in which this study was made, is a flat valley broadening and rising gently to the west-northwest from Glendale, located in the mouth of the valley. It is approximately 20 miles long and 10 miles wide. It is bounded on the east by the Verdugo Mountains, on the south by the Hollywood and Santa Monica Mountains, on the west and northwest by the Santa Suzana Mountains and Simi Hills, and on the north by the Sierra Madre Range. The only direct opening to the coast of any appreciable dimension is the pass at Glendale, between the Hollywood and Verdugo Mountains. Prevailing summer winds, westerly at Santa Monica on the coast, southwesterly over the down-town section of Los Angeles, and southeasterly over Glendale and Burbank, outline the trajectory of the sea air as it enters the Valley.

It is the purpose of this discussion to show that while the general phenomenon is similar, there are distinct differences in the structure of the air and in the process of formation of stratus overcoastal valleys as compared to the immediate coast; and to comment on methods of forecasting time of development and dissipation. We present here the results of a series of captive-balloon soundings to show (1) the process of dissipation of stratus in the mornings; (2) how the temperature inversion is destroyed or greatly reduced by heating of the valley floor during the early afternoon; (3) how the height of the inversion varies with changing surface temperature; (4) how the sea breeze reestablishes the inversion in the late afternoon; and (5) how subsequent radiation at night leads to further development of the inversion and finally to the formation of stratus.[2]

We had planned to remodel several of the returned radiometeorographs, expand their temperature and pressure scales, and make free-balloon soundings in the usual manner applied to radiometeorographs, except with very low ascension rates. However, because of the great amount of work involved in rebuilding and calibrating the instruments, this idea was abandoned in preference to captive-balloon soundings which could be made with only one instrument. Owing to a late start with this phase of the study and to difficulties involved in attempting captive-balloon soundings at a busy airport due to aviation hazards, we were able to take only one series of soundings before the radiometeorograph project was discontinued at Burbank.

The instrument was remodeled and other arrangements were made in time to select June 16 as representing a proper situation (with regard to the stratus) for a series of soundings. No other favorable conditions occurred after that date before the radiometerorograph project was terminated.

In order to show how the above-mentioned diurnal changes take place, the plan was to take the first sounding as near the time of maximum temperature as possible and to follow that with others about 3 hours apart. The first sounding was begun at 1:40 p. m. It required from 20 to 25 minutes to reel out the 1,800 feet of line and reel it in again. Due to airplane traffic interference, the second sounding was delayed from 4:40 p. m. until 5:15 p. m. This allowed time to evaluate the data of the first flight before beginning the second. It was evident from the first flight that our 1,800 feet of line was not sufficient to carry the instrument up to the base of the primary inversion. The third flight was begun at 8:55 p. m., and the last one at 10:28 p. m. Stratus began forming during the latter ascent, and an overcast at 400 feet had formed before the instrument was reeled in. The altitudes reached by the last two soundings were less than the first two owing to the increased wind velocity which carried the balloon out farther horizontally.

This series of soundings is very interesting of itself, especially since very little data of this kind have been collected in relation to the problem of California coastal stratus. It is regrettable that more than one such series could not have been taken in order to add more weight to the arguments presented below. Although this series is given a leading place in this discussion, in reality it only serves to verify ideas already formed through experience with other evidence.

An illuminating picture of the diurnal changes in the vertical temperature structure is presented in figure 1. Curve 1, representing the regular 6 a. m. ascent, shows an adiabatic lapse rate from the surface, up through the clouds, to the base of the inversion. This is the usual situation on foggy [3] mornings as indicated by all available soundings, such as those by airplane at North Island and Oakland and by radiometeorograph at Burbank. That very nearly a dry adiabatic lapse rate was maintained until the stratus cleared is evidenced by the fact that the clouds decreased from overcast to scattered within 15 minutes of the time the clearing temperature[4] was recorded. The temperature structure at this time is indicated by the dotted line at T_c.

The second ascent represented by curve 2, indicates that a dry adiabatic lapse rate continued, probably until shortly before this ascent was made; for the dry adiabatic

[1] See literature cited at end of paper.

[2] Acknowledgement is due H. R. Byers and L. P. Harrison for helpful criticism of the manuscript. We are also indebted to California Institute of Technology for the loan of their receiving and recording equipment, and to Capt. O. C. Maier and Louvan Wood for advice and assistance with the radiometerograph; also for the able assistance of H. C. Harvey and C. A. Cole in making the soundings.

[3] "Foggy", used to indicate high fog (stratus) as well as dense fog, and in the same sense hereafter.

[4] The clearing temperature is defined as the surface temperature (assuming dry adiabatic conditions) which corresponds to the temperature at the base of the inversion at the time of clearing.

lapse rate which exists above point C_2 could only have been established by a vertical transport of heat from the surface. It appears reasonable, in view of the uniform wind direction, to conclude that the base of the inversion has now risen to point L.

The base of the inversion has risen as a result of insolation, and by this time has reached a point which no longer bears any relationship to the depth of the sea breeze; for the depth of the sea breeze is a function of the onshore pressure gradient. In this connection, we note that an interesting development has begun, namely, the appearance of a minor inversion at B_2. An analysis of curve 2 shows first, a shallow layer A_2B_2 characterized by a super adiabatic lapse rate, then an isothermal layer B_2C_2, and finally, a layer above C_2, presumably extending rapidly at points B_2 and B_3 than at the surface. At point D, the existence of a sharp inversion and an abrupt shift in the wind direction from southeast to northwest, which was absent on the second ascent, is noted. The northwesterly wind represents advection of air which has been heated by contact with a warm surface. This warm surface could well have been the upper portion of the coastal hills, which become intensely heated through insolation due to the relatively clear atmosphere above the surface layer. The coastal hills (Hollywood and Santa Monica Mountains) extent in a general west-northwest direction along the south side of the San Fernando Valley, paralleling the coast line and hence a northwest wind at Burbank could have had an appreciable history over land surface before reaching Burbank.

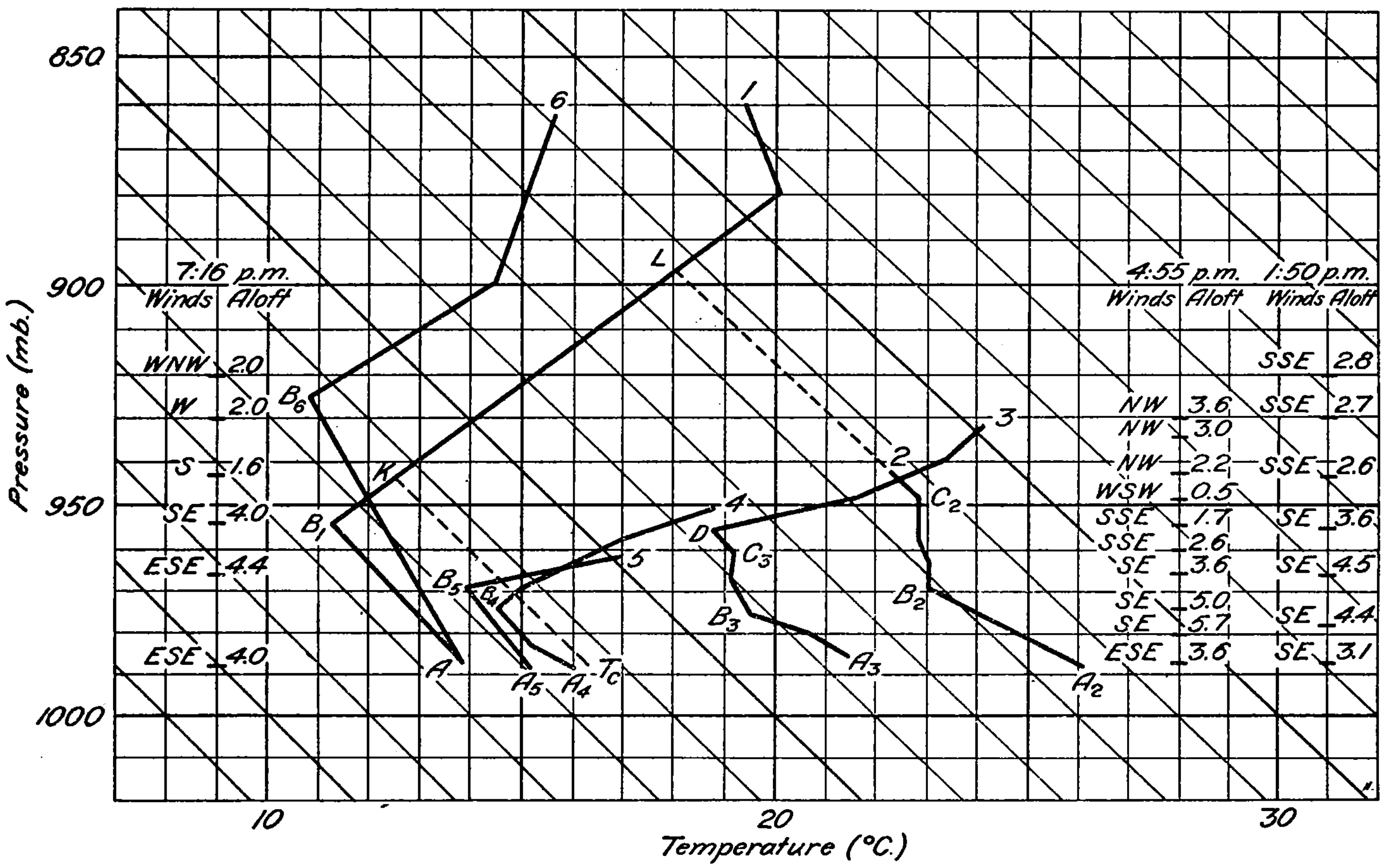

FIGURE 1.—Temperature curves of radiometeorograph soundings on an adiabatic chart: Free-balloon soundings, curves 1 (6 a. m., June 16) and 6 (6 a. m., June 17); captive-balloon soundings, curves 2 to 5 inclusive, at 1:40 p. m., 5:15 p. m., 8:55 p. m., and 10:28 p. m.

to L, with a dry adiabatic lapse rate. The corresponding upper air winds indicate that while a uniform direction prevails throughout, the greatest velocity is from point B_2 to near the surface. We shall consider then that point B_2 represents the top of the fresh sea breeze and that the layer B_2C_2 represents a mixing zone between the fresh and old marine air.

The third ascent up to point D, shows the same structure with respect to temperature and wind as the second ascent. The actual values of temperature are approximately four degrees cooler. This can be accounted for best as the result of advection; for there normally exists a marked temperature gradient from the interior to the coast, and a southeast wind being a sea breeze tends to lower the temperature. The super-adiabatic lapse rate in the surface layer on each of these ascents can perhaps be attributed to the intense rate of heating at the ground, and to the fact that advection was proceeding more

By the time of the fourth ascent the minor inversion at B_2 and B_3 has now become a marked inversion at B_4. That this inversion does not correspond to D of the previous ascent is illustrated by the fact that the southeasterly current extends beyond point B_4, whereas at D there was an abrupt change in the direction of the wind. It is also worthy of note that the amount of cooling at the various levels between the third and fourth ascents is roughly proportional to the wind velocities of the 4:55 p. m. observation.

The fifth ascent is similar to the fourth except for a slight increase in the elevation of the base of the inversion. The rate of cooling between the fourth and fifth ascents has diminished considerably from that between the previous ones. A brief consideration of the temperature gradient between Burbank and the coast will clarify this decreased rate of cooling. The maximum temperature gradient from Burbank to the coast occurs simultaneously with the maximum temperature at Burbank, and conversely, the minimum near the time of minimum temperature. Therefore, with a uniform flow of air from the coast we should expect the greatest rate of cooling near the time of maximum temperature, other things being equal. Actually, the problem is not so simple due to the factors of insolation and radiation. In this case the greatest rate of cooling occured between the third and fourth ascents.

Stratus clouds formed while the fifth ascent was being made. The first ceiling height was 400 feet, and this agrees closely, assuming the stratus to be about 100 feet thick, with the inversion at B_5. Another significant fact is that a dry adiabatic lapse rate was maintained after nightfall from the surface up to point B_5. Some have been of the opinion that after nightfall a ground inversion will rapidly develop in the absence of clouds. This observation would tend to indicate that the haze layer, which is always prevalent preceding the formation of stratus, is sufficient to prevent the development of a

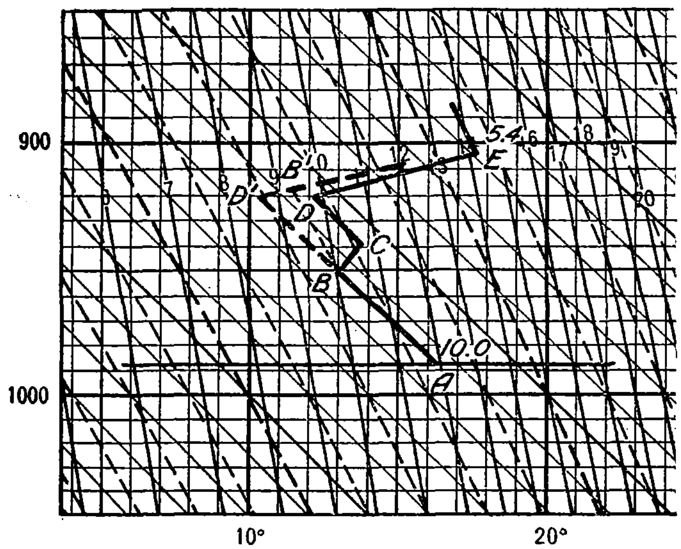

FIGURE 2.—Illustration on pseudoadiabatic chart of a method whereby the top of the stratus may build up.

ground inversion. The average temperature-dewpoint difference [5] in relation to ceiling height at the time stratus first forms also indicates that approximately a dry adiabatic lapse rate prevails from the surface to the clouds.

The remarkable increase in depth of the stratus clouds and the attendant rise in the top, as indicated by the regular ascent of the following morning, was due to an increased onshore pressure gradient resulting from cyclogenesis over the plateau. This increase in depth always occurs with the development of a low pressure area over the plateau, sometimes with astonishing rapidity.

The frequent persistence of haze in the San Fernando Valley during the late morning and afternoon has been rather baffling. One would assume that, with comparatively intense solar heating of the valley floor, an adiabatic lapse rate would prevail through out a considerable depth and therefore the haze would be carried aloft, resulting in greatly improved visibility. However, the presence of low level minor inversions, as found by the writers, will account for the frequent persistence of the haze, for they effectively hinder its vertical distribution.

Since the synoptic developments from the afternoon of June 16 until the morning of the 17th were not typical of the usual, it is thought fitting to describe briefly the "normal" behavior of the stratus. We do not wish to infer that there is not often considerable variance in the behavior of the tratus but merely that there is a type of behavior occurring with sufficient frequency to be considered a normal condition.

In general, the top of the stratus is at about the same elevation for several successive mornings, while the ceiling when the stratus first forms may vary appreciably. It also is very noticeable that the first ceiling in the evening is much lower than the last ceiling before clearing of the same morning, and also considerably lower than the top of the stratus before sunrise the next morning.[6] Under these circumstances, the behavior of the stratus is indeed difficult to explain from the prevalent idea of a single inversion; for in that case the stratus should first form at the base of the inversion and gradually work down so that the top could not rise.

By means of the double inversion structure (see fig. 2) many variations in the behavior of the stratus may be accounted for.[7] For example, stratus may form first at the base of the minor inversion, created as previously described, through advection, while at the same time considerable radiational cooling is presumably occurring at point D, the point of maximum moisture contrast. Now point D may undergo sufficient cooling to reach point D', thereby establishing a continuous adiabatic lapse rate from D' to the surface; and hence a building up of the stratus to B' will occur, assuming moist adiabatic conditions within the cloud. It is probable that cooling from D completely to D' would not be necessary to allow for the clouds to build upward. It would need cool only sufficiently for slight turbulence to penetrate the diminishing inversion at B.

A rather complex vertical temperature structure in the afternoon was first indicated in the spring of 1936 when, through the courtesy of United Air Lines, we were furnished temperature readings at 200-foot intervals. A few of these are reproduced in figure 3. The single horizontal line indicates the level at which stratus first formed; the double horizontal line the level of the top of the stratus on the following morning.

The problem of forecasting the time of development and the height of stratus for areas along the immediate coast of California has its difficulties, but for coastal valleys at an appreciable elevation above sea level, such as the San Fernando Valley, the problem is more complex. The stratus forms along the immediate coast presumably as a result of turbulence and radiational cooling in the moist surface layer. Over coastal valleys, however, advection plays an important role. Therefore, a forecast for these areas must be approached through an understanding of the situations under which advection of moist or dry air takes place, as well as the effects and extent of turbulence and radiation. We shall comment on the general aspects of the problem without discussing any particular situation in detail.

It is not an easy matter to estimate the rate of flow of the moist air inland. The surface pressure gradient is so badly distorted by the effects of the mountains and the heating in the desert valleys that the true pressure gradient is very difficult to evaluate. The normal pressure gradient along the coast in summer calls for

[5] The average amount of ceiling per ° F. depression of the dew point for the 5-year period, 1933-37, for June, is 275 feet. This value was determined for the time stratus first formed in the evening, and for ceilings from 100 to 3,000 feet. Assuming a dry adiabatic lapse rate, the amount is 227 feet per ° F.

[6] The average difference between the last ceiling in the morning and the first ceiling of the following night, for the four year period, 1934-37, for June, is 447 feet. See also fig. 3.

[7] Bowie, Vernon, and Petterssen all mention the double inversion in their studies of the stratus but apparently they regard it as an exceptional case rather than the rule, such as seems to be the case in the San Fernando Valley.

winds from northwest to west. Yet, in the San Fernando Valley the prevailing direction in summer is southeast—directly opposite to the indicated gradient. This is due to the deflection of the flow by the mountain ranges that inclose the San Fernando Valley.[8] The marine air can not reach the Valley by flowing directly over the mountains owing to the "lid effect" of the warm air above it except when the marine air extends well above the elevation of these mountains. It must either flow up the circuitous course of the Los Angeles River or through a few, narrow, low passes. All these obstructions greatly complicate the rate of flow. A careful study of wind data, both surface and aloft, affords a vague means of reaching an estimation. Wind data are not available in sufficient detail to make a complete picture possible.

no direct evidence is available to the forecaster at the time of the evening forecast as to the structure of the air over the area with which he is concerned. The absence of direct aerographic measurements at appropriate times has forced the forecaster to resort to whatever indirect methods he can devise. Vernon's use of pressure comparisons between Eureka and Oakland in order to estimate the depth of the moist layer over Oakland is an attempt along these lines. Once the height of the single inversion above the coastal station is determined, assuming an adiabatic lapse rate within the stratum, it is a simple task, with the aid of a pseudoadiabatic diagram and any concurrent, early evening temperature, dew point, and pressure, to locate the height of the condensation level with respect to the base of the inversion. The time of

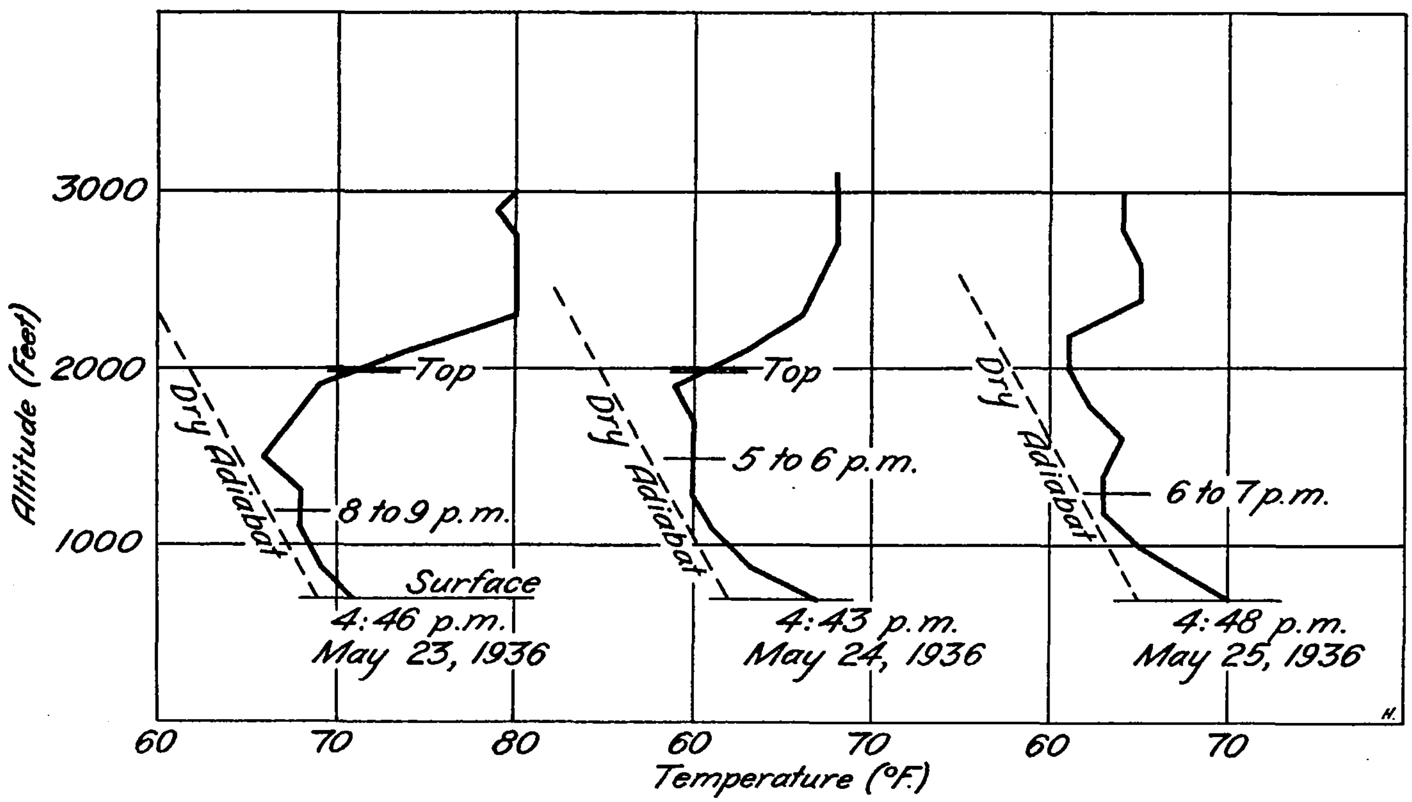

FIGURE 3.—Temperature-altitude curves of data received from air line pilots. The thickness of the cloud layer is much greater on the 25th under the influence of a deepening low pressure trough over the plateau.

Knowledge as to the thickness of the moist stratum, the lapse rate within it, and the moisture distribution above the marine layer, as well as within it, can only be had by means of aerographic soundings. The series of soundings represented in figure 1 is enough to indicate that one sounding a day taken in the morning is a poor indicator as to what can be expected for the coming evening. For purposes of forecasting time of development of the stratus and its height, the most opportune time for a sounding is 3 to 4 hours after the time of maximum temperature. It is only in this way that the changes brought about by insolation, mixing, and later advection of fresh marine air can be evaluated with any degree of accuracy. The morning sounding is of value primarily for forecasting time of clearing of the cloud.

Except for the temperature data available only irregularly from pilots' observations taken over the Airport in departing or arriving on regular scheduled airline trips,

condensation is then forecast from an estimation of the rate of lowering of surface temperature, since the cloud first forms at the top of the marine layer.

In connection with determining the height of the condensation level from surface data, Lt. Floyd B. Wood found, in his study on "The Formation and Dissipation of Stratus Clouds Beneath Turbulence Inversions," that the computed condensation level is usually lower than the observed cloud base. Some allowance must be made accordingly in the computed value. For levels below 500 meters, his curves show that the necessary allowance is very small. In the great majority of cases in the San Fernando Valley, the condensation level is below 500 meters.

Although a considerable amount of investigation has been done at Burbank with hope of discovering some such dependable relation as Vernon [9] found between pressure difference at Eureka and Oakland, and the depth of the

[8] A good description of the topography of the region is given by H. R. Byers—Characteristic Weather Phenomena of California.

[9] E. M. Vernon—The Diurnal Variation of Ceiling Height Beneath Stratus Clouds, Monthly Weather Review, Jan. 1936.

sea breeze, no reliable relation has been found so far. Reference to the series of soundings herein described may well suggest a cause for this failure. The complexity of a double inversion, such as seems to be a frequent case at Burbank, makes comparison of pressures in estimating the depth of the sea breeze too delicate to be detectable above the greater effects on pressure of heating in mountain valleys, of reduction to sea level, etc. Brown of the Burbank Office of the Weather Bureau has made an extensive study of the relation of pressures at Burbank and those at stations in the San Joaquin Valley, and Colorado River Valley, and along the coast, as to the *time of formation* of stratus at Burbank. His curves give favorable results when used together with a night to night comparison of the general synoptic situation. His comparisons are extremely delicate in some cases; for example, each 0.01 inch lower pressure at Fresno than at Burbank gives, on the average, a one hour earlier development of the cloud. Furthermore, the frequent large departures of individual cases from the average, makes use of his data advisable only with caution.

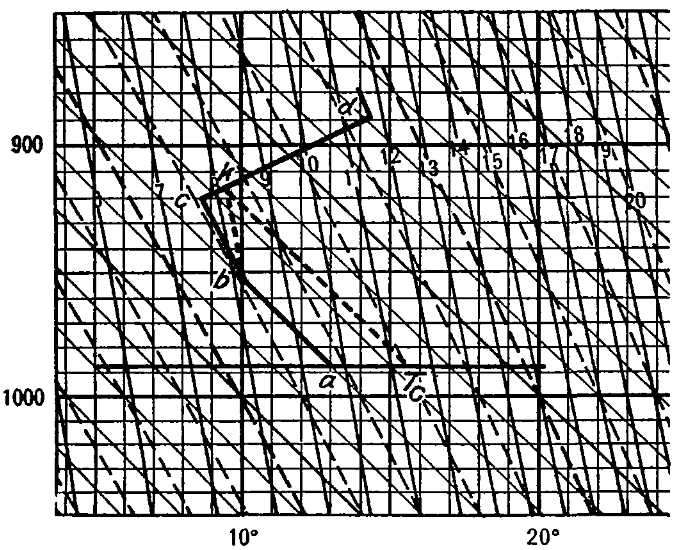

FIGURE 4.—Illustration of method of determining T_c on pseudoadiabatic chart.

The problem of forecasting the clearing of summertime stratus at Burbank has received considerable study during the past 2 years. Previously, the problem of forecasting the formation of these clouds was receiving most of the attention of the forecasters. This was largely because the forecasts for clearing were generally more accurate than were those for forming.

The first approach to the present method of forecasting clearing came with the use of the pseudoadiabatic chart. With the aid of this chart it was noted that the surface temperature at which the clouds began to break could often be determined within reasonable limits.

Occasionally forecasts were based on estimations of the time the clearing temperature, T_c, would be reached. This was done by noting the temperature behavior on a previous foggy day. However, variability in temperature behavior on individual days gave rather discouraging results. It was finally decided to prepare some average temperature curves (described below) whereby the time of clearing could be determined from the value of T_c.

Since this method of forecasting the clearing of stratus clouds has been previously described elsewhere,[10] this section will be devoted mostly to the application of this method in daily use and to some results obtained thereby.

[10] Dr. Irving P. Krick, Journal of the Aeronautical Sciences, July 1937, p. 12.

The method of determining T_c is illustrated in figure 4. The curve *abcd* is the temperature curve on the pseudoadiabatic chart. Point *a* represents the surface temperature, *b* the temperature at the base of the clouds, *c* the temperature at the top of the clouds and base of the inversion, and *d* the temperature at any point in the inversion layer which is sufficiently above *c* to remian above the clouds until they have dissipated. The point *k* is determined by drawing through *b*, a line parallel to the nearest specific humidity line on the chart. This line intersects *cd* at *k*. From *k* the dotted line follows a dry adiabatic path to the surface where T_c is indicated. Once T_c has been determined, the clearing time can be ascertained by means of curves such as shown in figure 5.

These curves represent the average hourly change in temperature, based on 6 years of record, when low stratus clouds or dense fog prevailed. A separate curve was prepared when each of the following conditions prevailed from 5 a. m. to 6 a. m.: (1) Dense fog, (2) Stratus with ceiling approximately 500 feet, (3) Stratus with ceiling approximately 1,000 feet, and (4) Stratus with ceiling

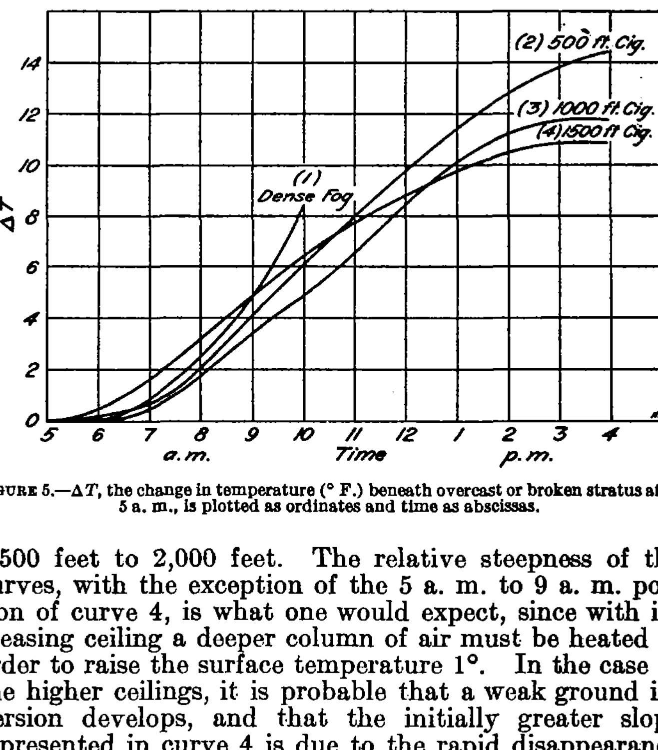

FIGURE 5.—ΔT, the change in temperature (° F.) beneath overcast or broken stratus after 5 a. m., is plotted as ordinates and time as abscissas.

1,500 feet to 2,000 feet. The relative steepness of the curves, with the exception of the 5 a. m. to 9 a. m. portion of curve 4, is what one would expect, since with increasing ceiling a deeper column of air must be heated in order to raise the surface temperature 1°. In the case of the higher ceilings, it is probable that a weak ground inversion develops, and that the initially greater slope represented in curve 4 is due to the rapid disappearance of this inversion after sunrise.

It should also be pointed out that these curves may be used for estimating the time that any given ceiling will be reached. One degree Centigrade increase in temperature represents a theoretical increase in ceiling of about 115 meters, which is equivalent to 210 feet per degree Fahrenheit.

If airplane observations or radiometeorograph observations are available, it is a very simple task requiring but a few seconds to determine T_c after the data have been plotted on a pseudoadiabatic chart. Further, data secured by these means are sufficiently accurate to allow for very reliable determinations of T_c. Hence, any deviation in the indicated clearing time from the actual will have but one source of error, namely, the temperature curves. This source of error is unfortunately unavoidable.

If radiometeorograph or airplane observations are not available, the method may still be used with good results provided accurate information can be had as to the ceiling and thickness of the clouds, and the slope of the lapse rate in the inversion layer. For any given surface temperature, T_c varies directly with (1) the thickness of the clouds and (2) the steepness of the slope of the lapse rate curve in the inversion layer, as can be seen from figure 5. However, without accurate information no attempt should be made to use this method. It should be pointed out also that the application of this method assumes that the specific humidity remains fairly constant during the clearing process.

This information may often be had from scheduled air-line pilots, a very satisfactory source. Also nearby mountain stations can give this information, though in general, due to the fact that the elevation of the top of the clouds has to be estimated, the results therefrom are not always reliable. For example, an error of 500 feet in estimating the elevation of the top of the clouds will give a very unsatisfactory value for T_c. It is also often difficult to get an accurate concept of the lapse rate in the inversion layer; for the mountain station may be above the inversion layer, in which case this method cannot be used unless temperature readings are available from some other stations at an intermediate elevation. Also, early morning temperatures from such stations are invariably lower than the free air temperature of the same level. It has been found that early evening temperatures from such stations in the vicinity of Burbank, correspond well with the temperature at the same level on the airplane flight of the following morning from North Island.

Experience has further shown that this method may not be reliable when a ragged or variable ceiling prevails. Under such circumstances the thickness of the clouds cannot accurately be evaluated. Any other factor, such as a changing synoptic situation, which influences the thickness of the clouds will also make this method invalid, for T_c would then be a variable. The use of the surface temperature as as basis for computing T_c is apt to be unreliable in the case of comparatively high ceilings, especially if the clouds did not form until well after midnight. In such cases, temperature data should be available from the top or base of the cloud layer in order to compute T_c.

Some results are presented in table 1. It was decided to use for this purpose the results obtained during May and June of 1938, a period when daily morning radio-meteorograph observations were made at Burbank, and hence a period during which no doubt can exist as to the reliability of the source of the data. Under the heading, T_c, is the indicated time of clearing, and under the headings, BRKN, and SCTD, the time at which the clouds first became broken and scattered respectively. While the results are by no means perfect, broken or scattered clouds were reported within 1 hour of the indicated clearing time in approximately 80 percent of the cases, and in all cases within 1½ hours of the indicated clearing time. We therefore believe these results justify the use of this method of forecasting the clearing of California summer-time stratus clouds.

TABLE 1

Date	t_c	BRKN	SCTD
	a. m.	*a. m.*	*a. m.*
May 11	7:20	------	8:10
May 12	8:10	------	8:41
May 13	8:00	8:41	8:45
May 14	8:30	9:15	9:41
May 16	None	------	------
June 2	8:40	------	7:29
June 3	8:35	------	8:25
June 6	8:35	9:00	9:10
June 7	10:55	11:29	11:34
June 15	8:35	9:00	9:04
June 16	8:30	------	9:55
June 17	10:40	11:00	11:10
June 23	8:00	8:29	8:41
June 24	8:30	9:41	9:50
June 25	9:00	------	9:09
June 27	7:30	------	8:06
June 28	10:10	8:15	9:50
June 30	11:40	------	12:55

REFERENCES

(1) E. H. Bowie. The Summer Nighttime Clouds of the Santa Clara Valley, California. MONTHLY WEATHER REVIEW, 1933, 61: 40–41.

(2) E. M. Vernon. The diurnal Variation in Ceiling Height Beneath Stratus Clouds. MONTHLY WEATHER REVIEW, January 1936.

(3) Dean Blake. Further Conclusions from Additional Observations in the Free Air over San Diego, Calif. MONTHLY WEATHER REVIEW, June 1934.

(4) Sverre Petterssen. On the Cause and Forecasting of the California Fog. Journal of the Aeronautical Sciences, July 1936.

(5) Irving P. Krick. Forecasting the Dissipation of Fog and Stratus Clouds. Journal of the Aeronautical Sciences, July 1937.

(6) Lt. Floyd B. Wood. The Formation and Dissipation of Stratus Clouds Beneath Turbulence Inversions. Abstract-Bulletin of the American Meteorological Society, March 1938.

BIBLIOGRAPHY

[RICHMOND T. ZOCH, in charge of library]

By AMY P. LESHER

(This section will be resumed in the March issue—Editor.)

SOLAR OBSERVATIONS

[Meteorological Research Division, EDGAR W. WOOLARD in charge]

SOLAR RADIATION OBSERVATIONS, OCTOBER 1939

By IRVING F. HAND

Measurements of solar radiant energy received at the surface of the earth are made at nine stations maintained by the Weather Bureau, and at ten cooperating stations maintained by other institutions. The intensity of the total radiation from sun and sky on a horizontal surface is continuously recorded (from sunrise to sunset) at all these stations by self-registering instruments; pyrheliometric measurements of the intensity of direct solar radiation at normal incidence are made at frequent intervals on clear days at three Weather Bureau stations (Washington, D. C., Madison, Wis., Lincoln, Nebr.) and at the Blue Hill Observatory at Harvard University. Occasional observations of sky polarization are taken at the Weather Bureau stations at Washington and Madison.